Measurement of the rotor wake using PIV on a scaled turbine rotor in a water flume

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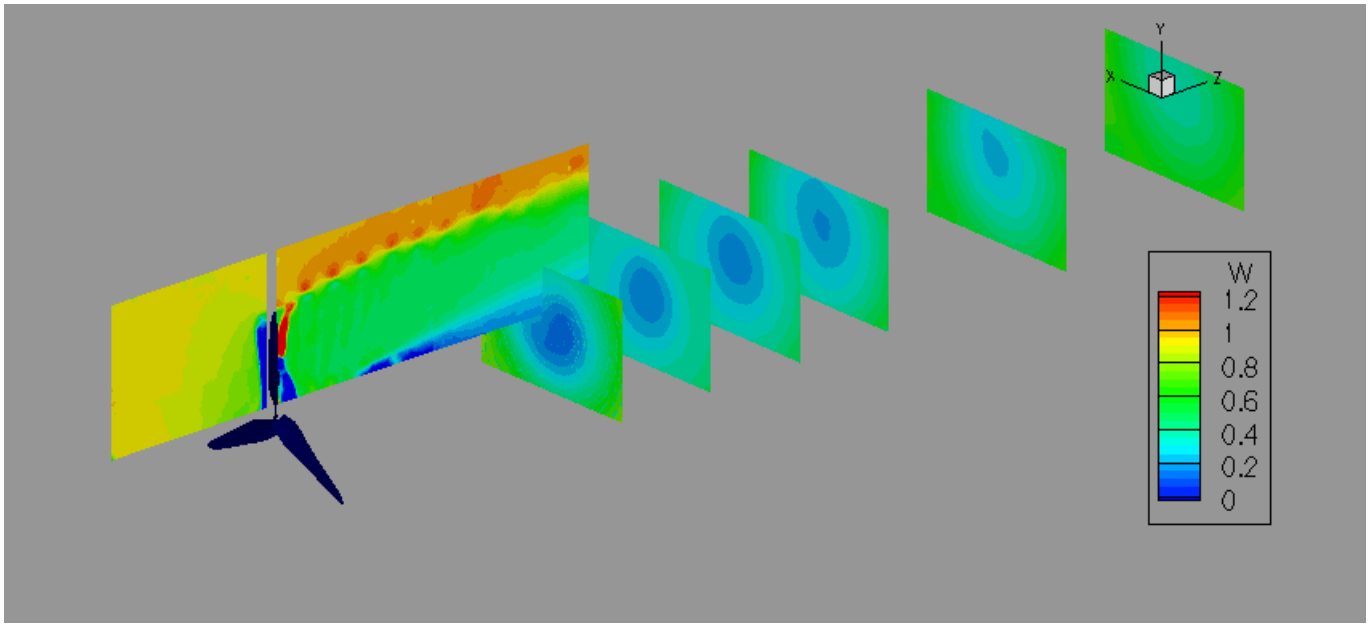

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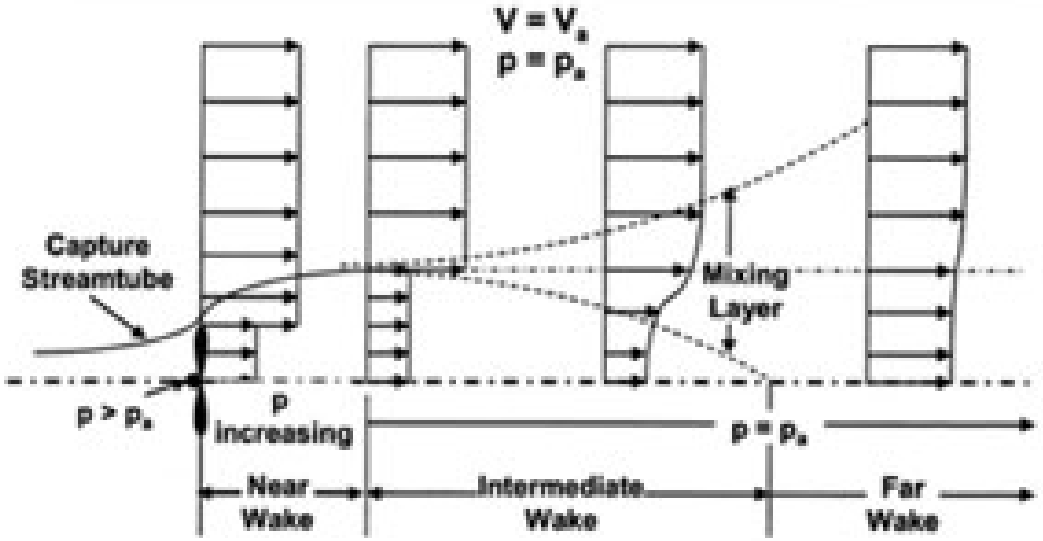
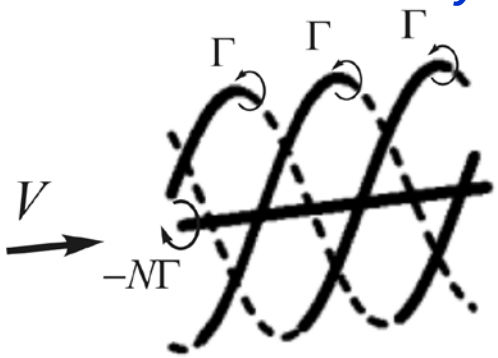
Motivation to this study is the incomprehensible wake!



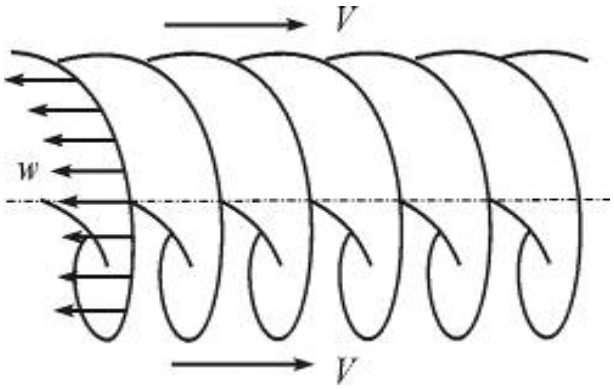
An alternative presentation of the wake: **near wake – far wake – turbulent wake**

The next motivation is to study of the wake behind Glauert rotor

Wake behind Joukowsky rotor - I

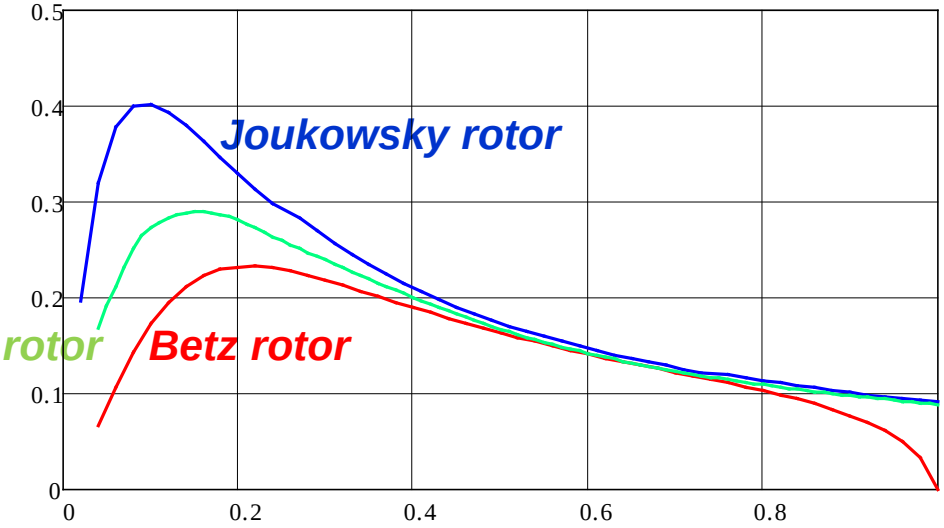


Wake behind Betz rotor - II

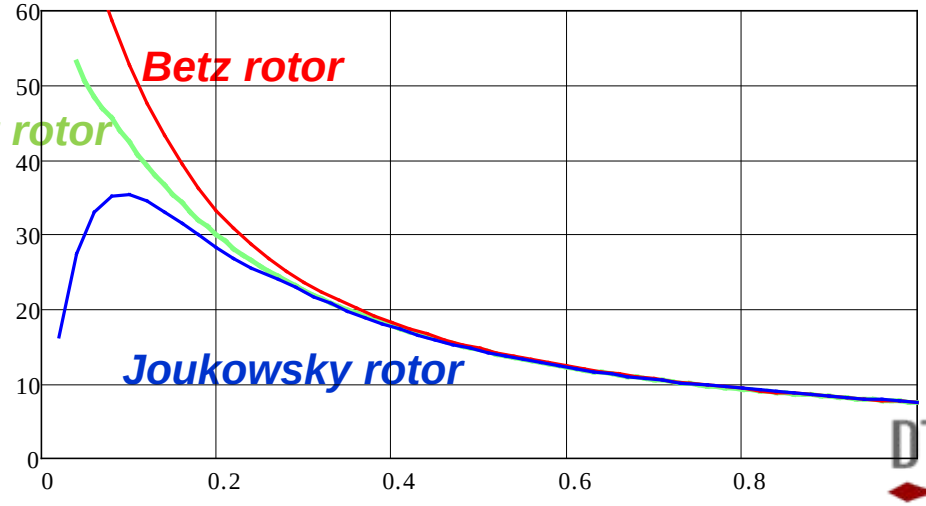


What is a wake behind Glauert rotor?

chord



pitch



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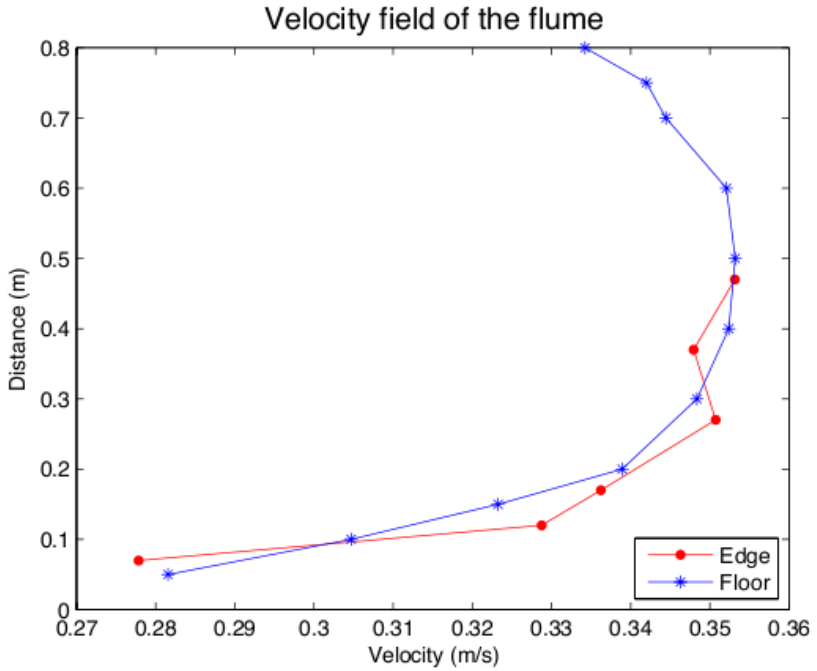
Flume

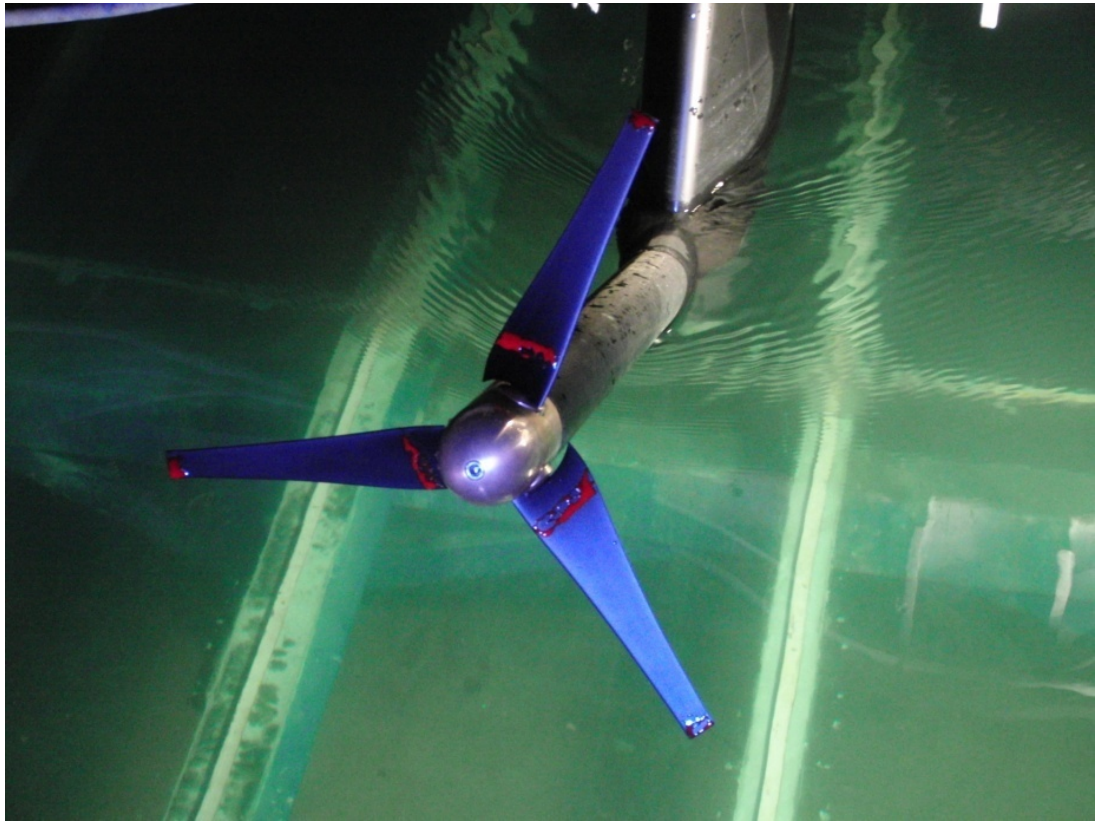
- V_0 = 0.38 and 0.5



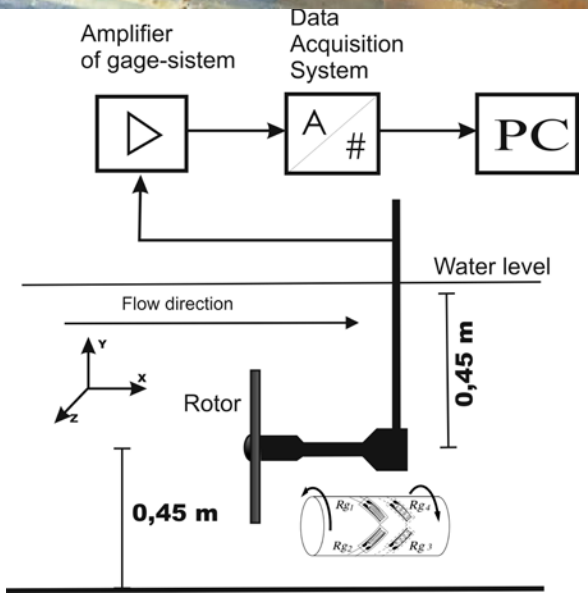
ROTOR

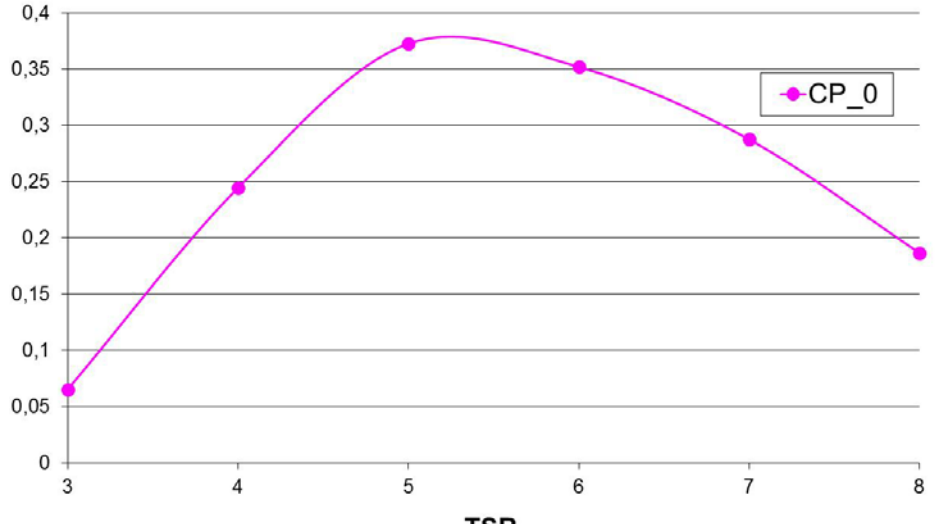
The current study is turbine by Glauert opt. for λ=5

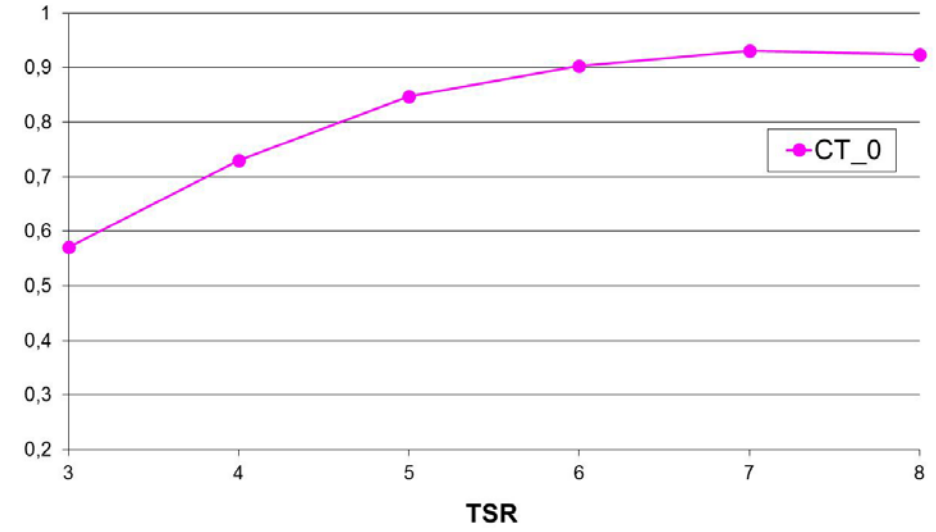
- D=0.35m
- SD7003 aerofoil
- Re = 20 000
- V_0 = 0.38 and 0.5



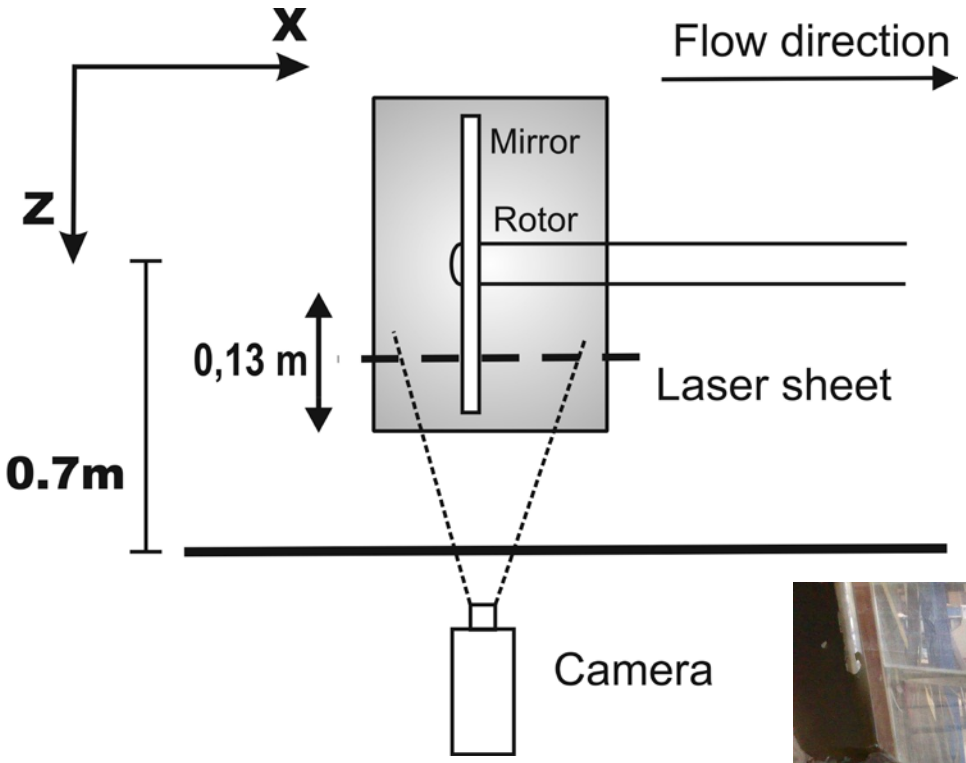
Measurement of the power and trust



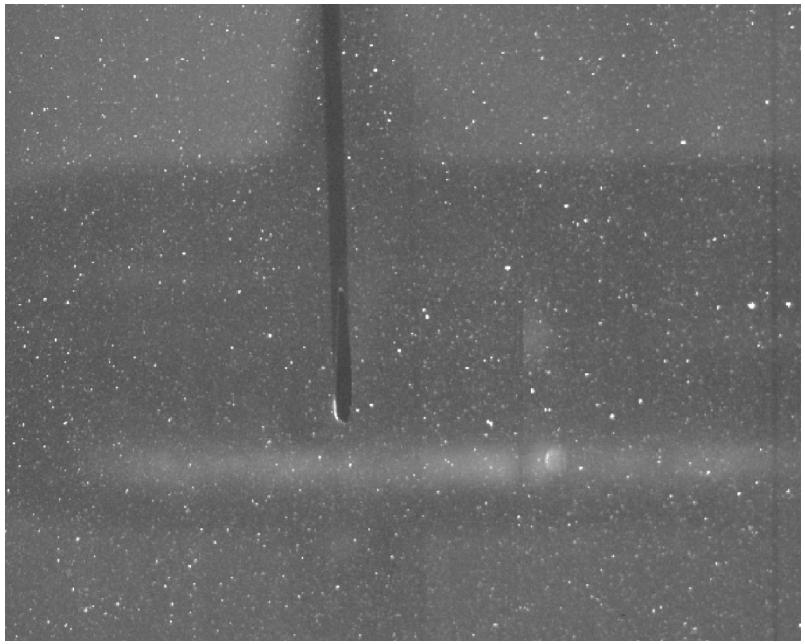


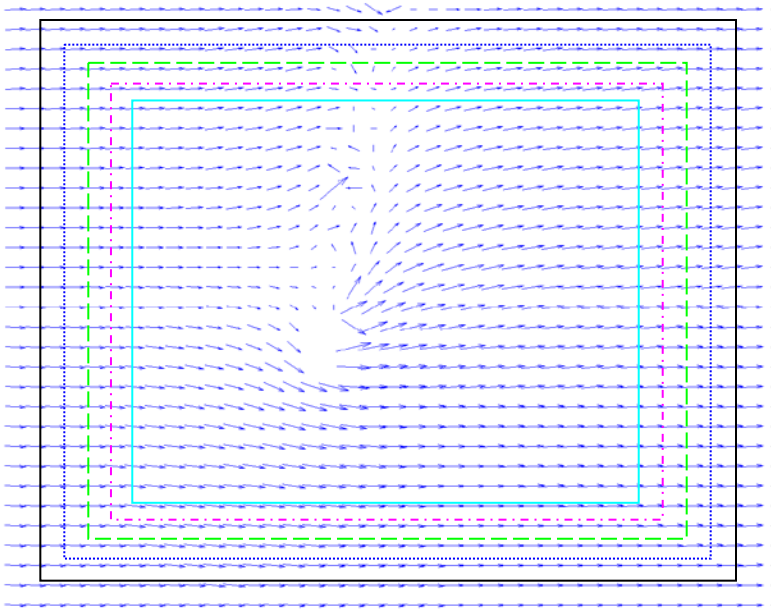


Measurement of the blade circulation



Blade circulation $\lambda = 3$

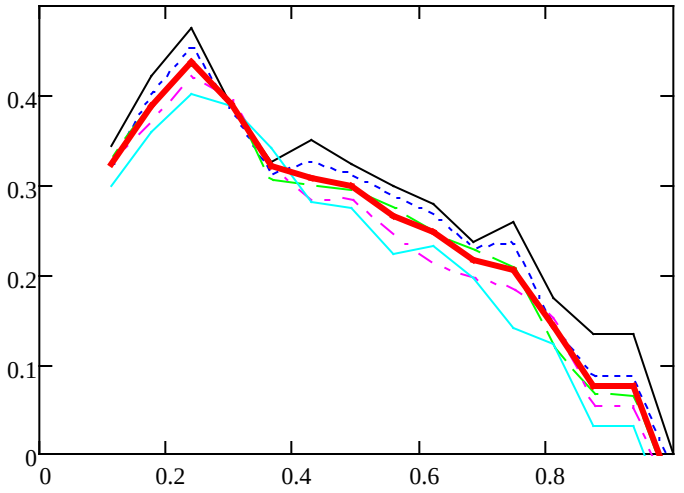




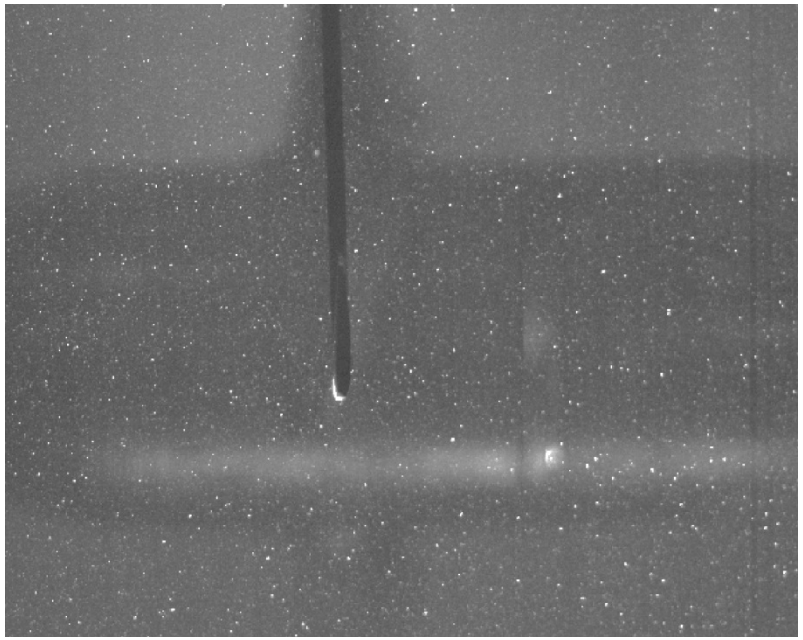
Circulation

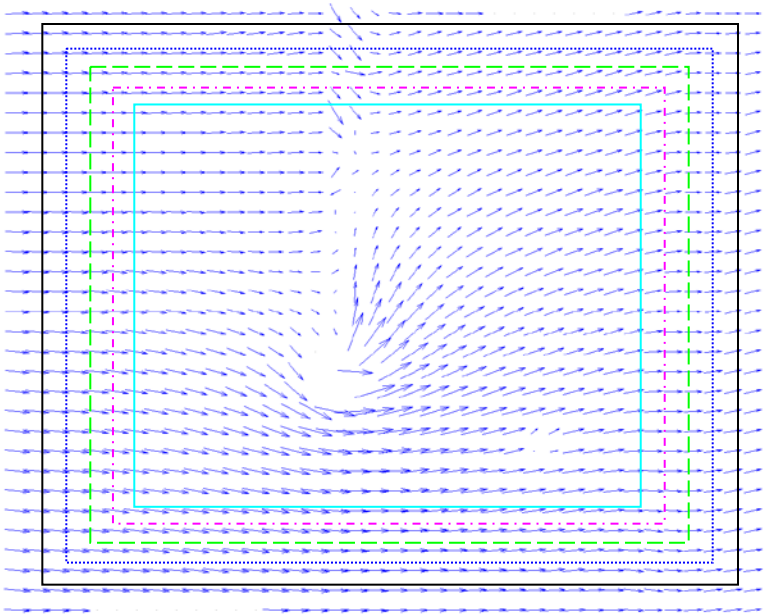
$$\Gamma = \oint \vec{u} \cdot d\vec{l}$$

$$\frac{\Gamma}{2\pi U_\infty R}$$



Blade circulation $\lambda = 5$

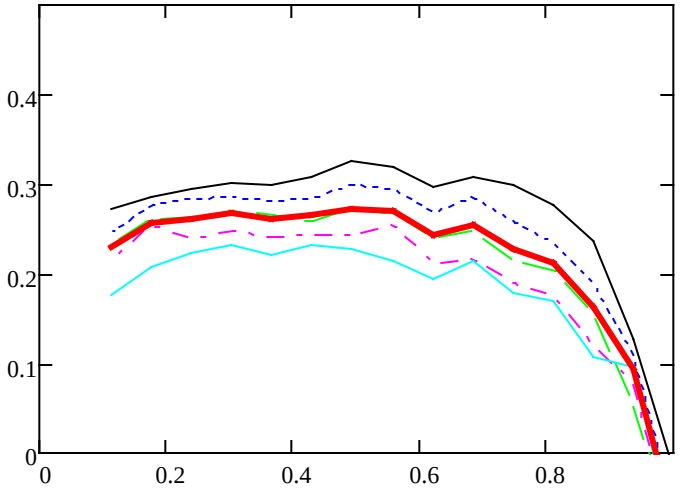




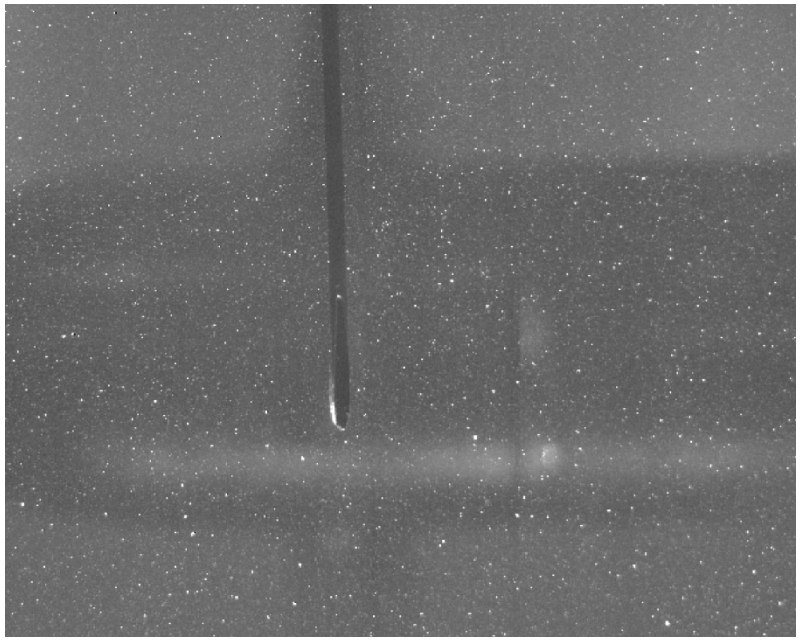
Circulation

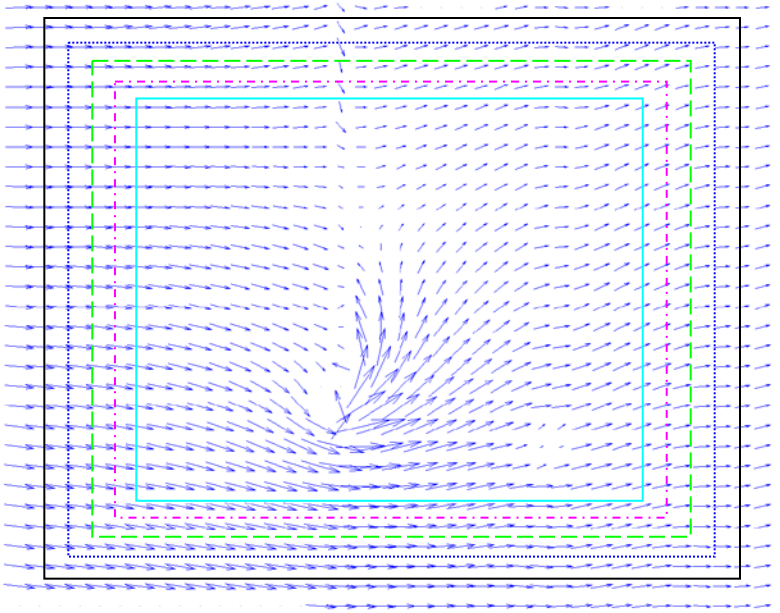
$$\Gamma = \oint \vec{u} \cdot d\vec{l}$$

$$\frac{\Gamma}{2\pi U_\infty R}$$



Blade circulation $\lambda = 7$

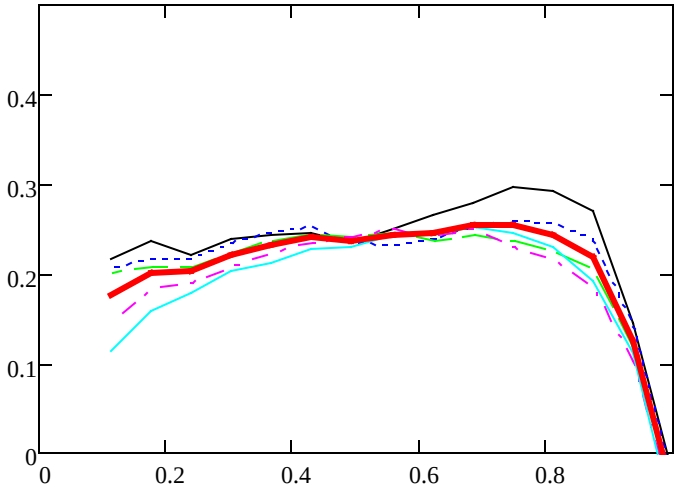




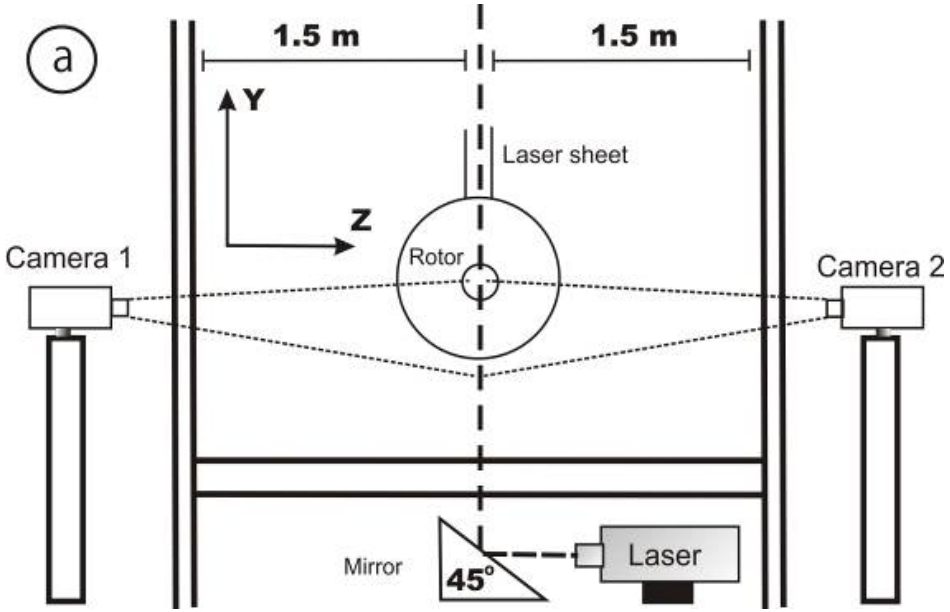
Circulation

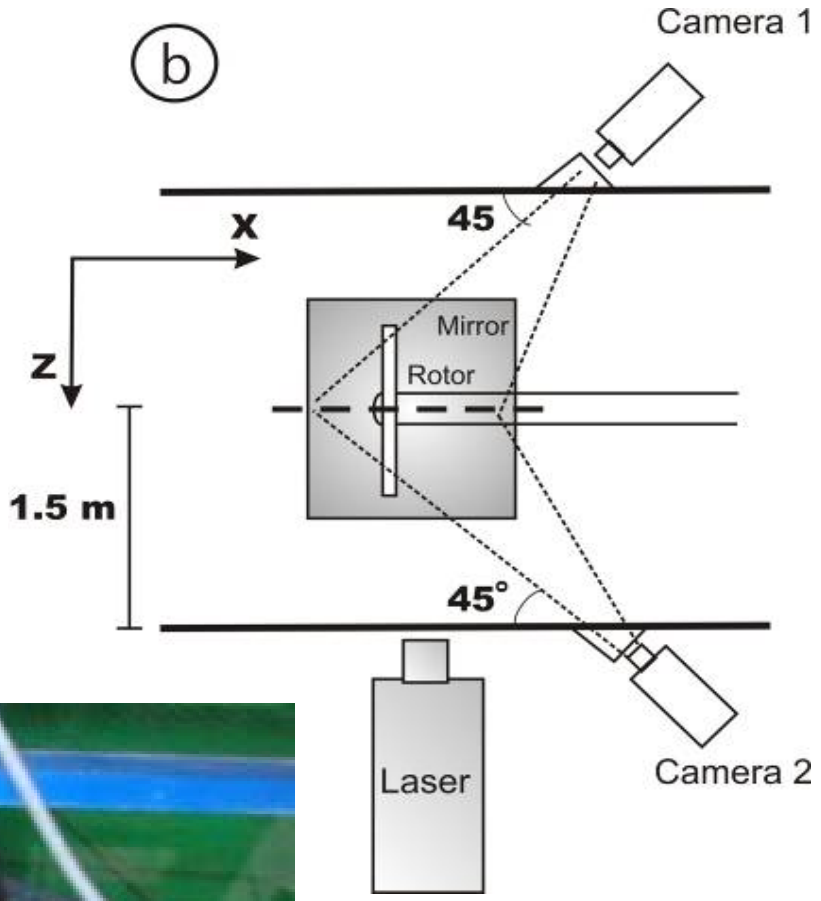
$$\Gamma = \oint \vec{u} \cdot d\vec{l}$$

$$\frac{\Gamma}{2\pi U_\infty R}$$



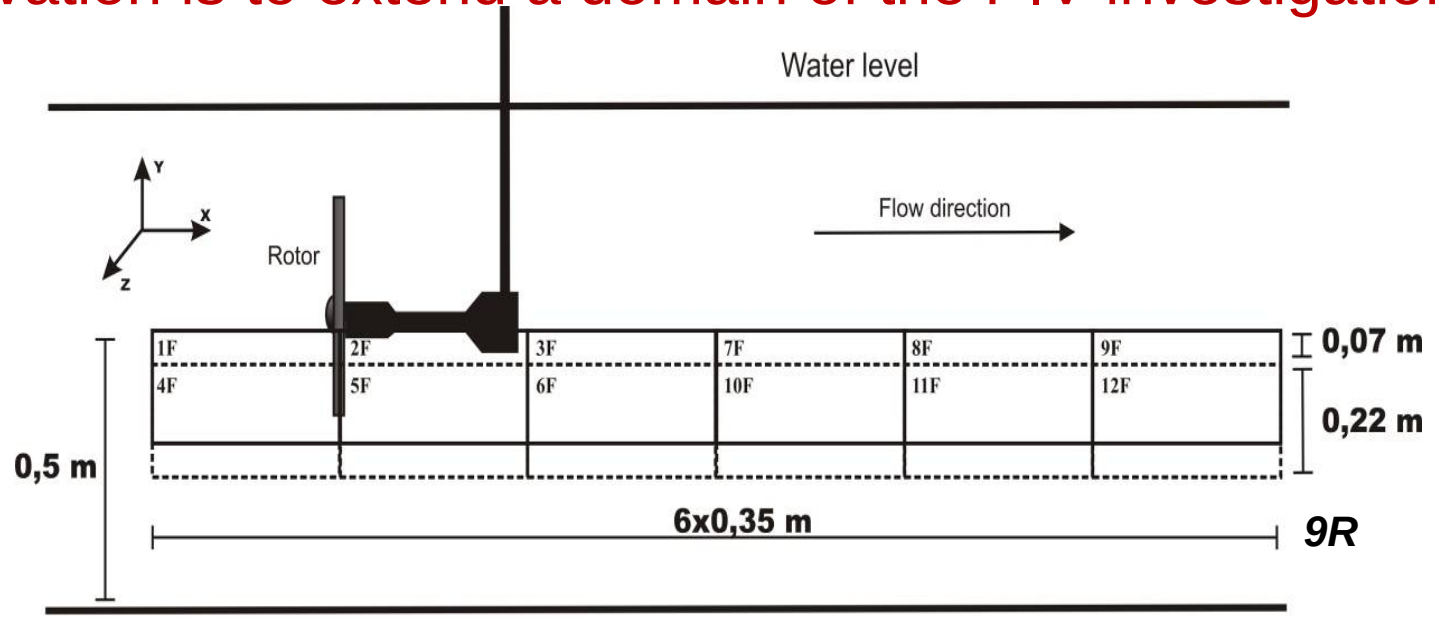
Sketch of the setup with stereoscopic PIV



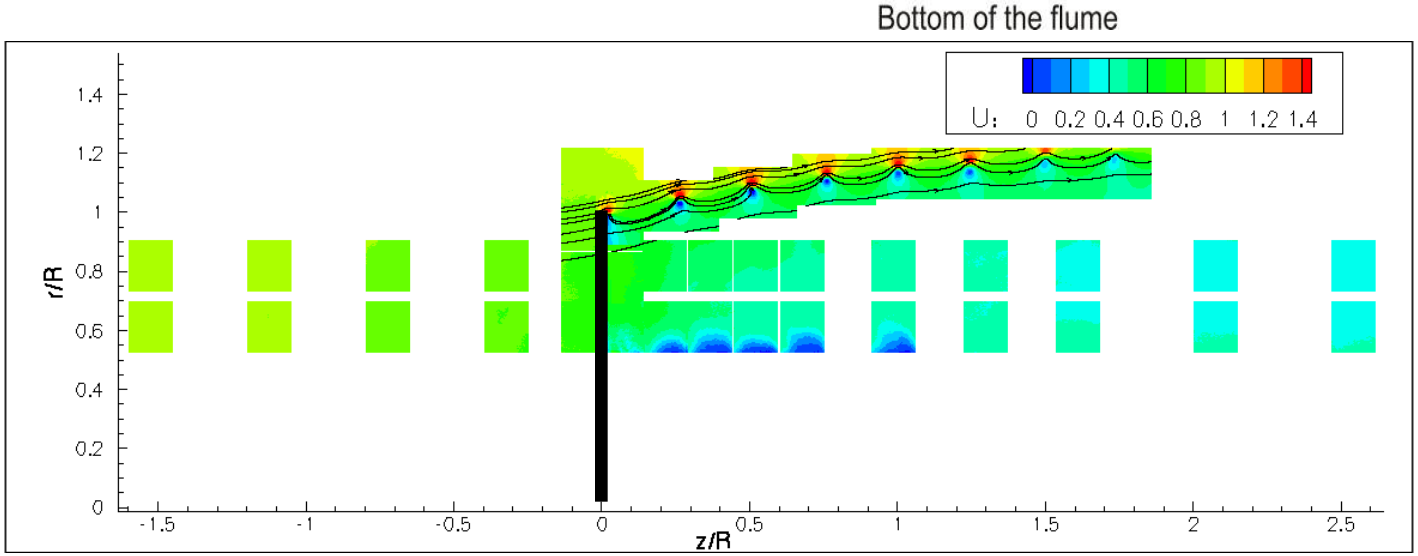


New motivation is to extend a domain of the PIV investigation

Sketch of 12 testing windows of the current experiment



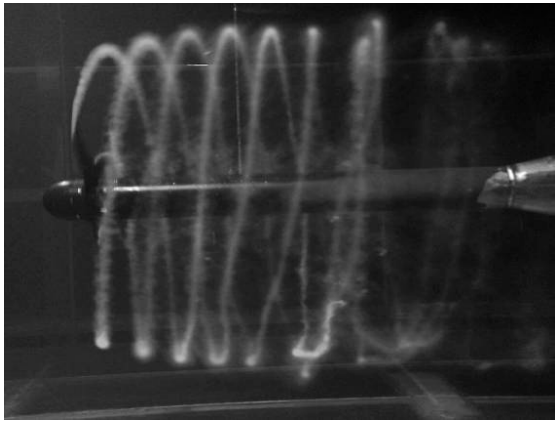
Sketch of the windows in the "MEXICO" PIV-experiment



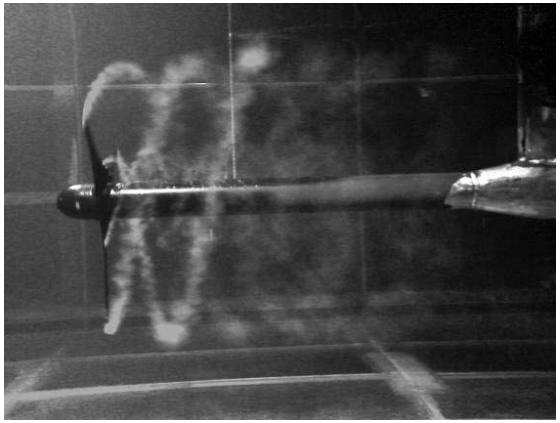
Visualizations of WT’s wake TSR=6

Visualizations of WT's wake for different TSR

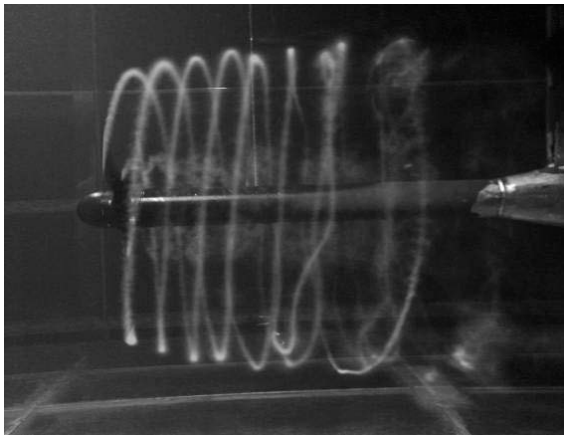
λ=6



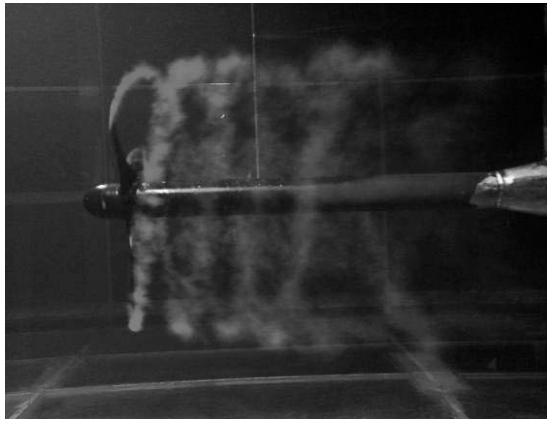
λ=4



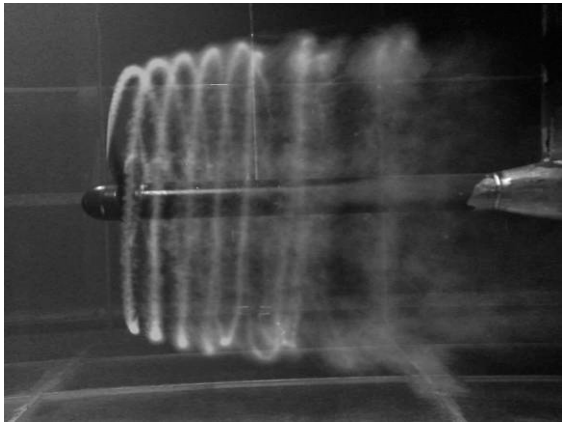
λ=7



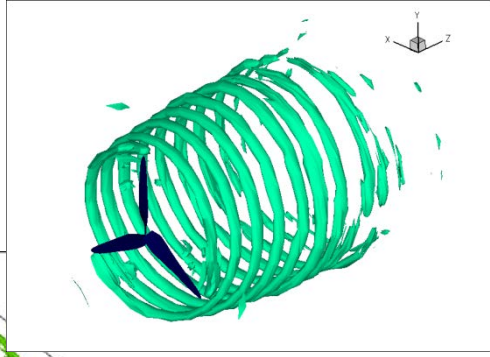
λ=5



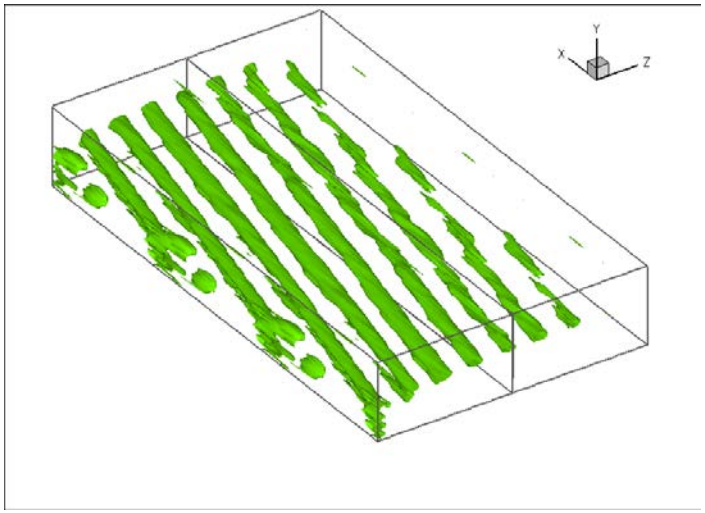
λ=8



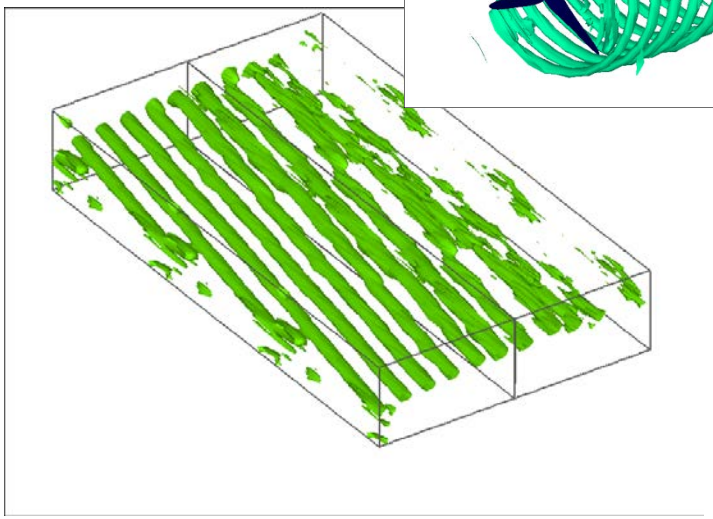
Tip vortex structure, unfolded, 0,15,30,45,60,75,90,105 deg



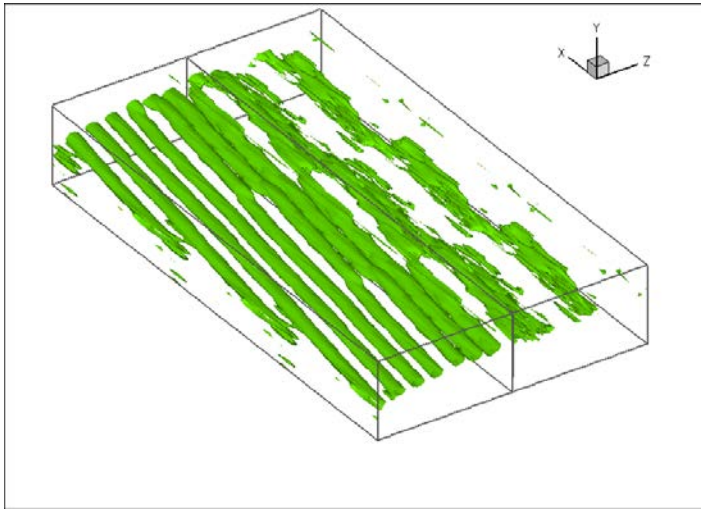
λ=4



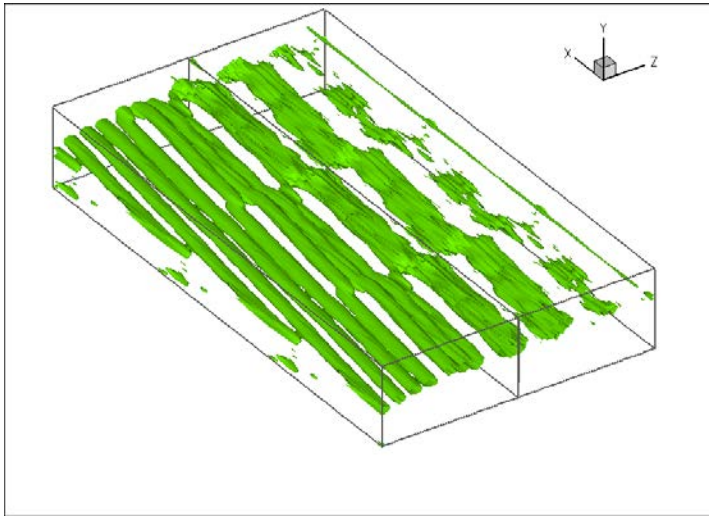
λ=5



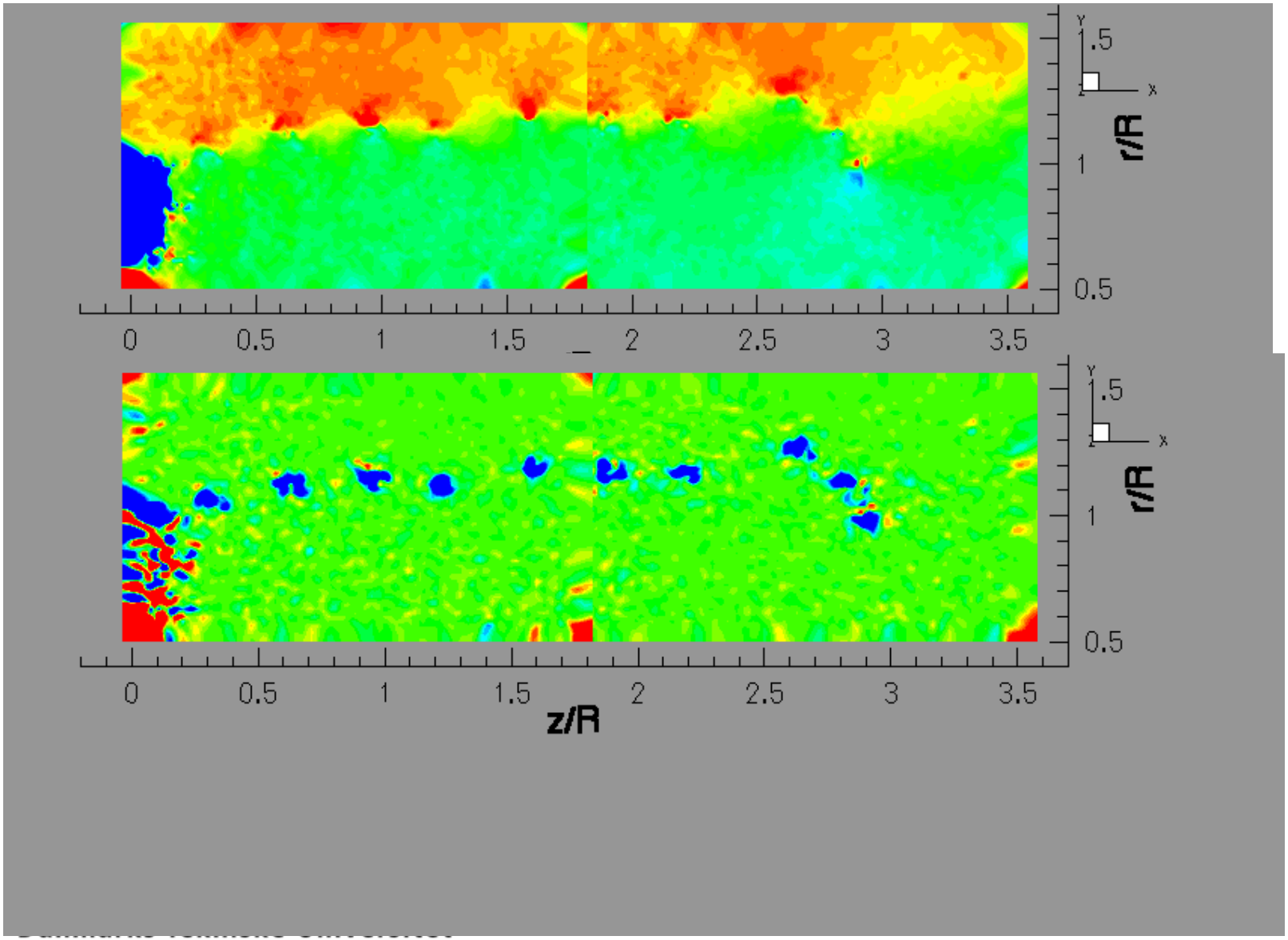
λ=6



λ=7



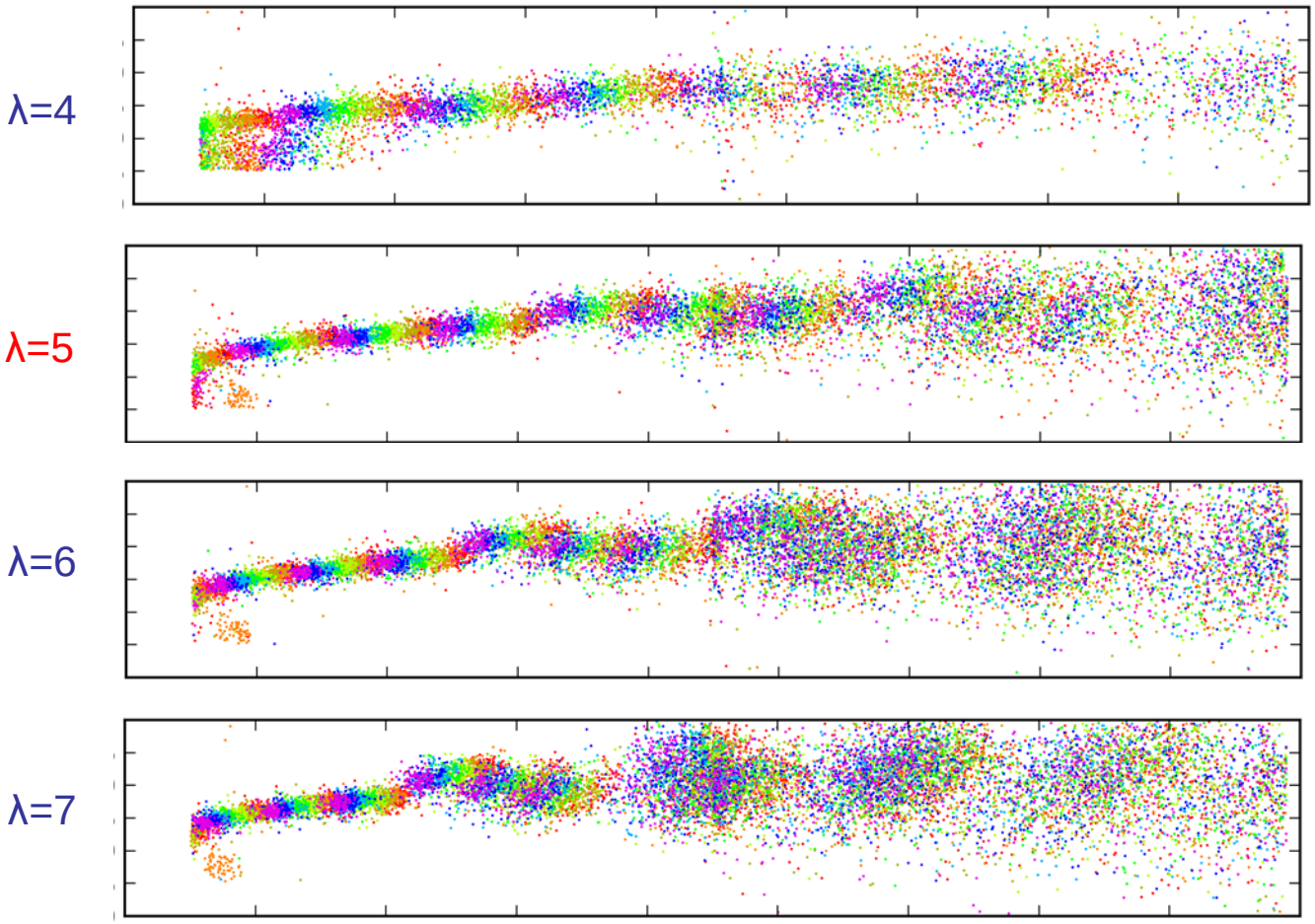
Axial velocity, TSR=6, 100 images



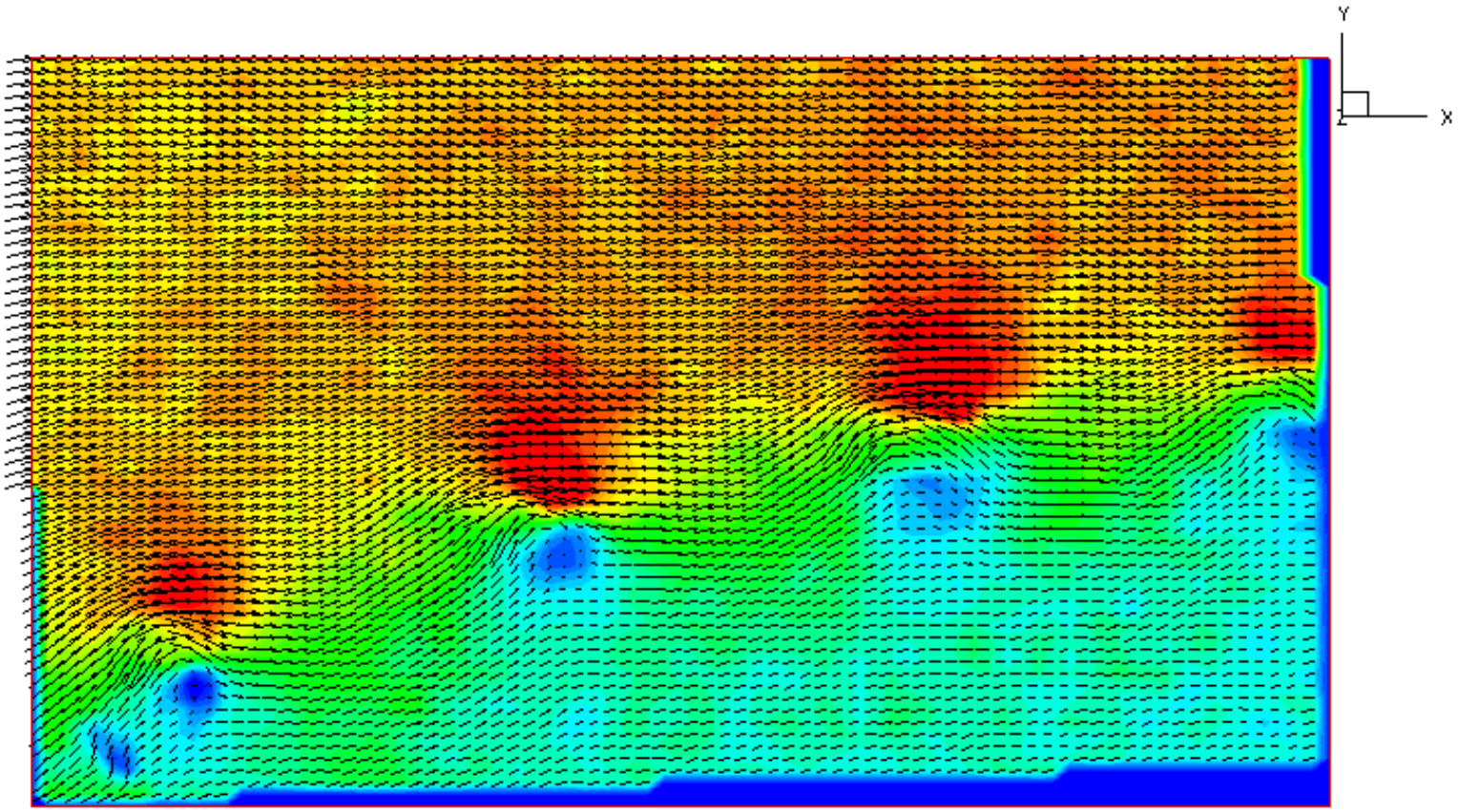
U ax.

Vorticity

Instantanious location of vortex center
0,15, 30,45,60,75,90,105 deg



Tip vortex and vectors, TSR=6

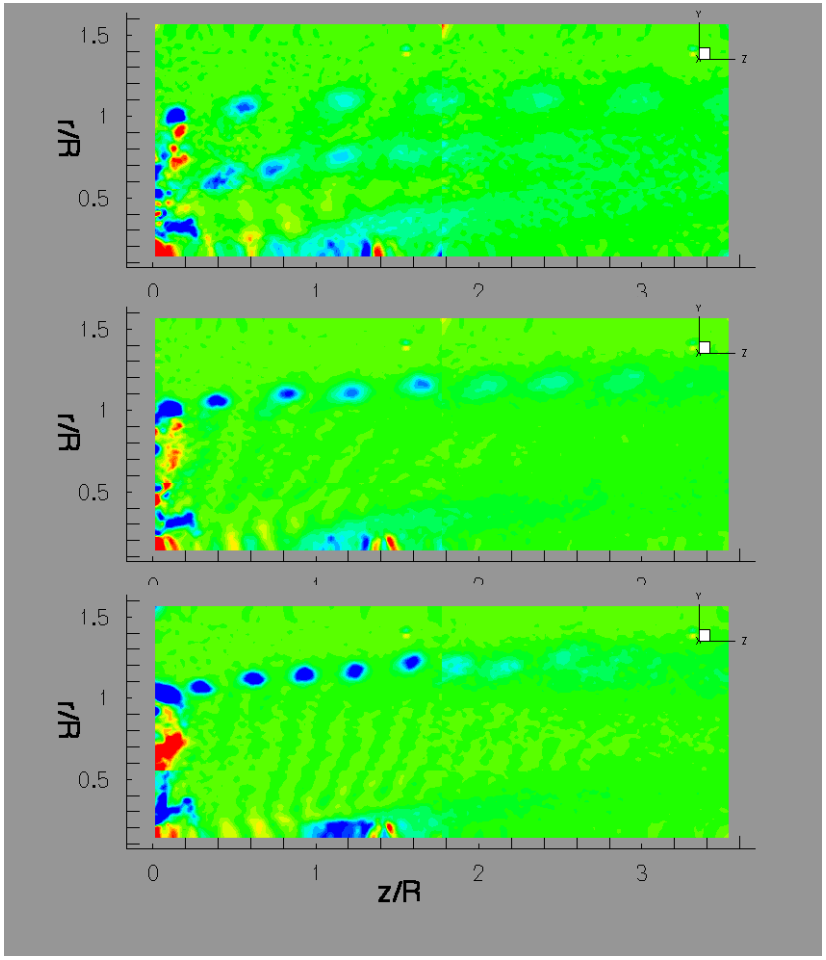


Tip vortex – vorticity, phase averaged, TSR=3-7

λ=3

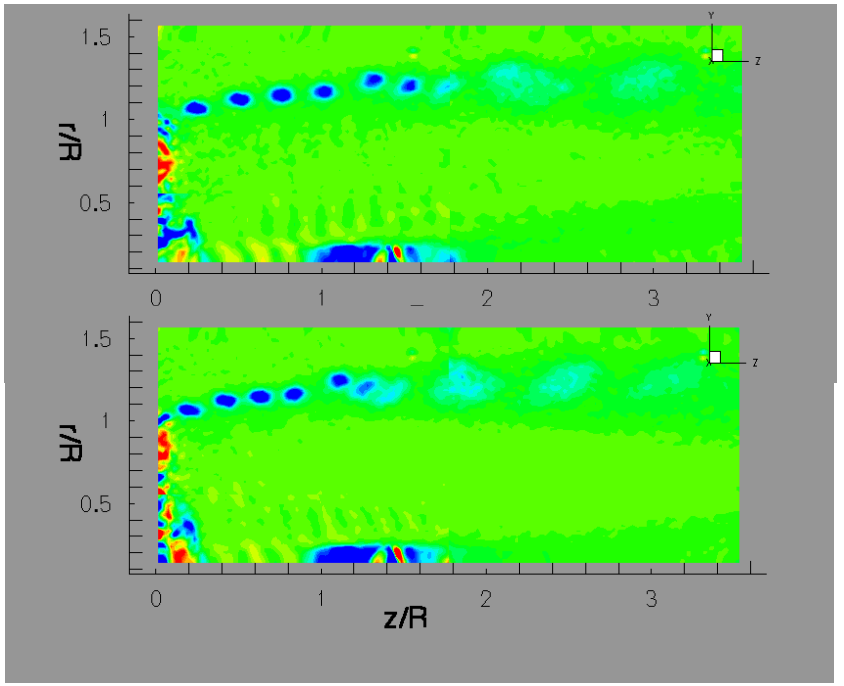
λ=4

λ=5



λ=6

λ=7



Axial velocity, phase averaged,TSR =3-5

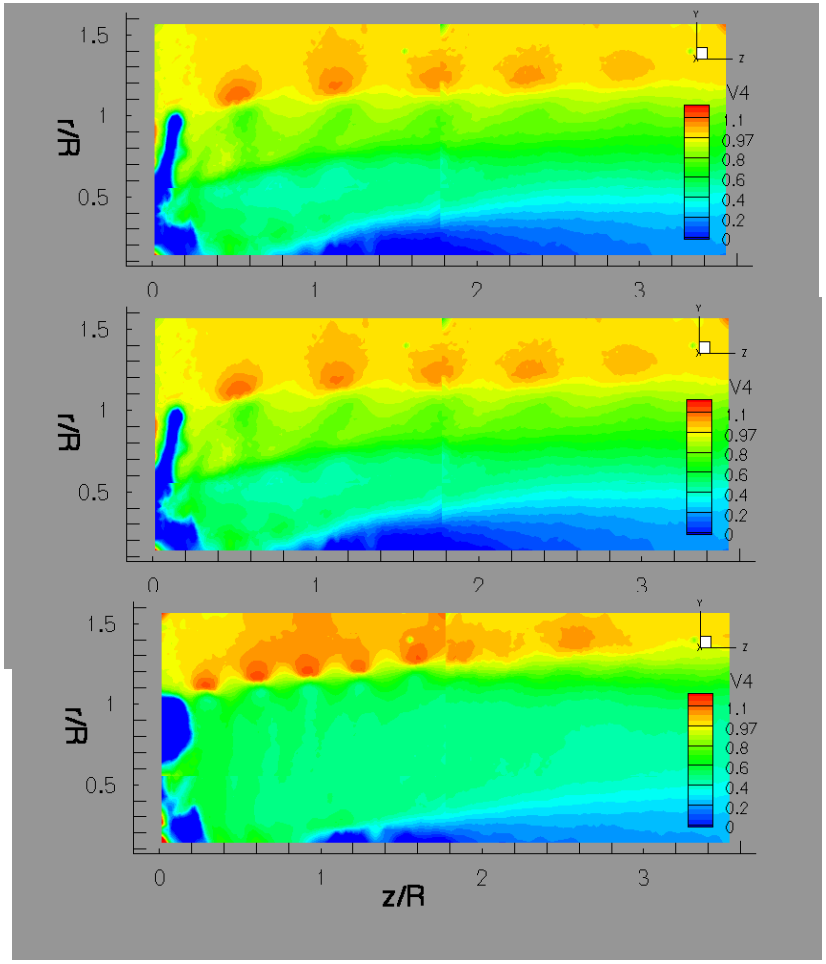
λ=3

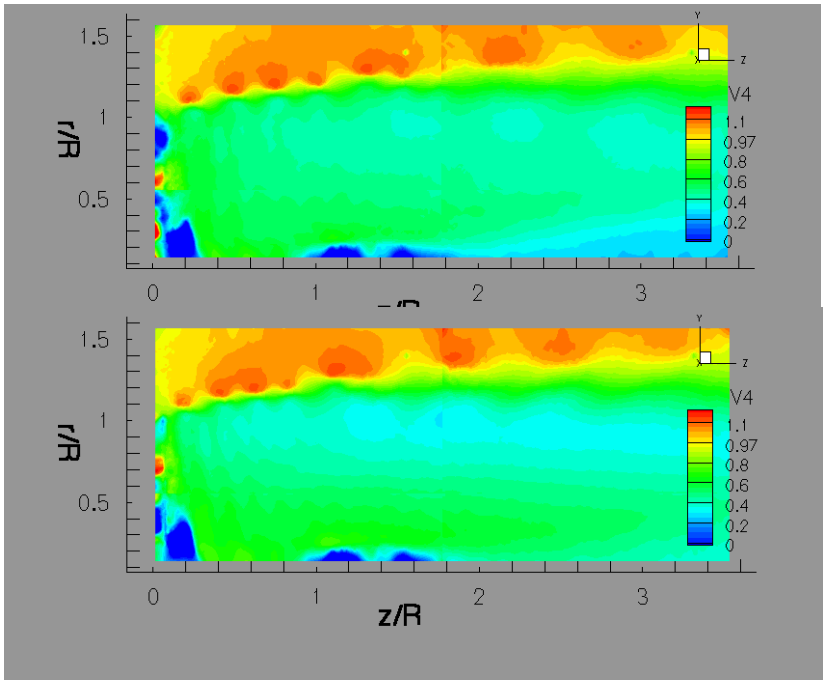
λ=4

λ=5

λ=6

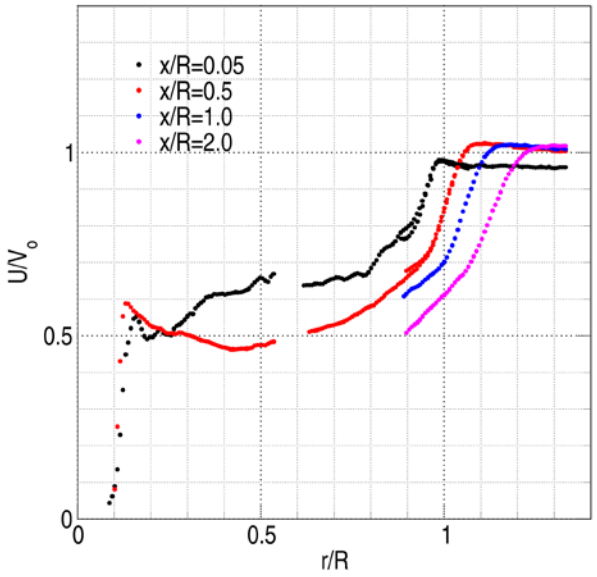
λ=7





Mean Axial Velocity U, TSR 4-7

4



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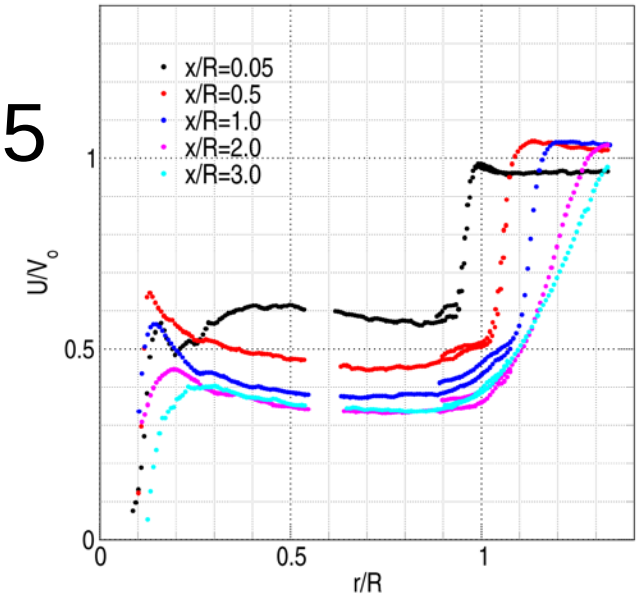

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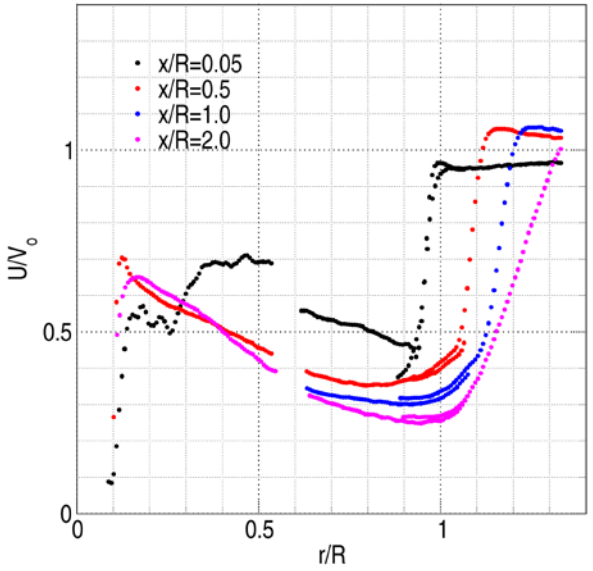

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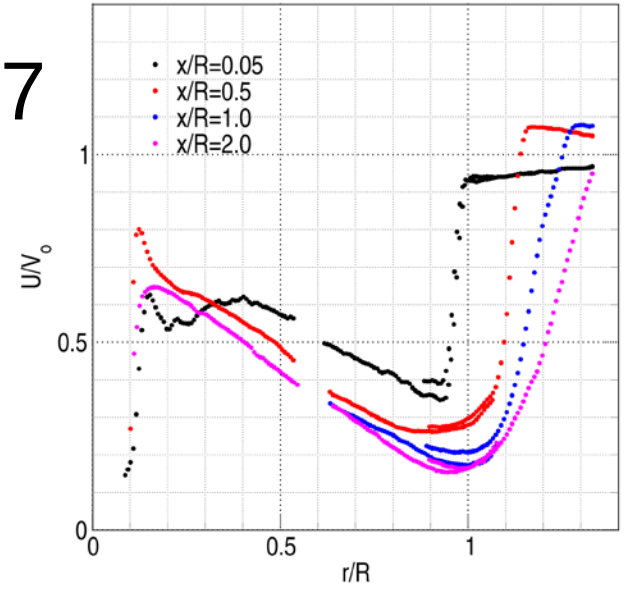


Axial velocity, U rms

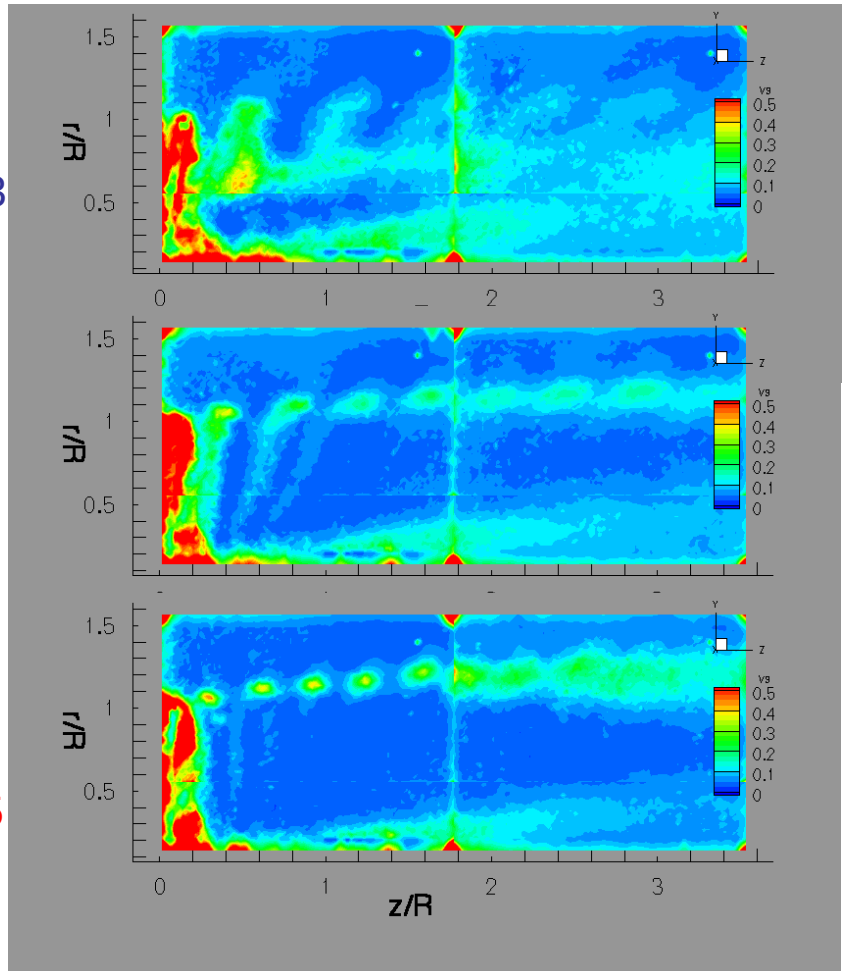
λ=3

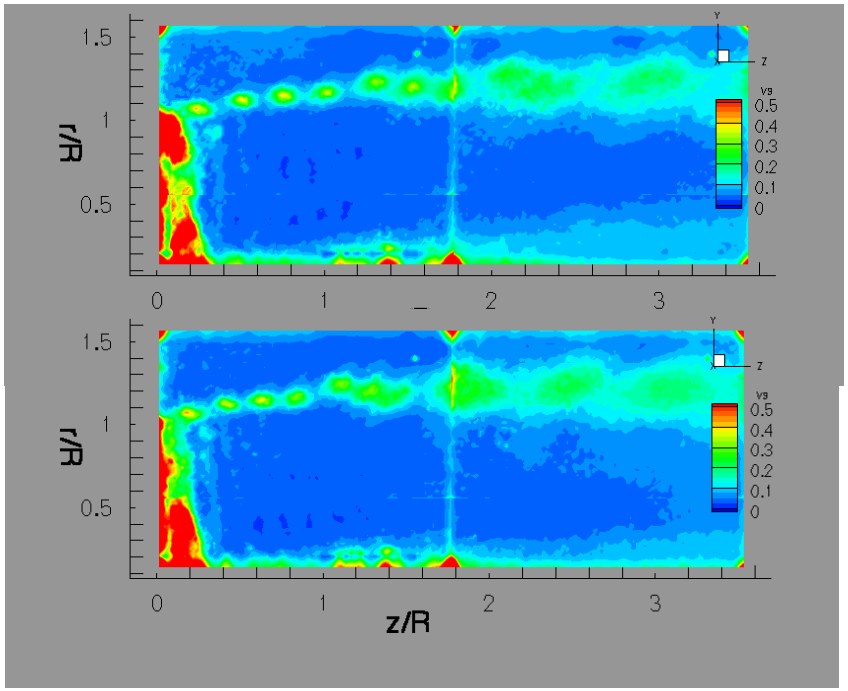
λ=4

λ=5

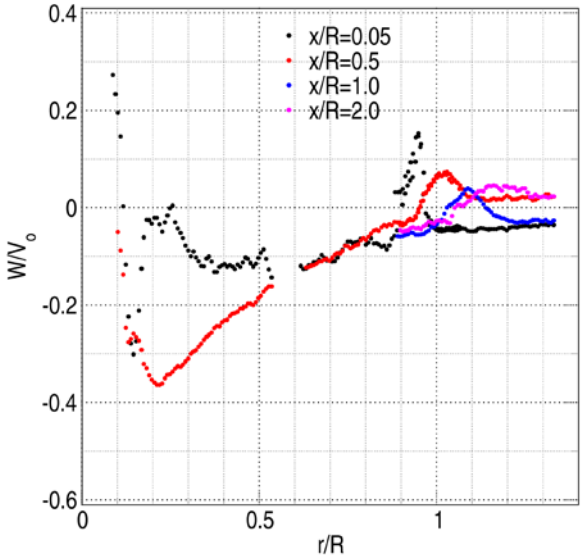
λ=6

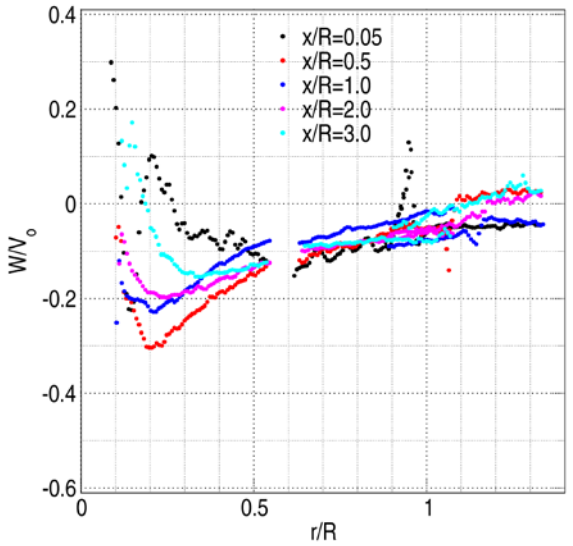
λ=7

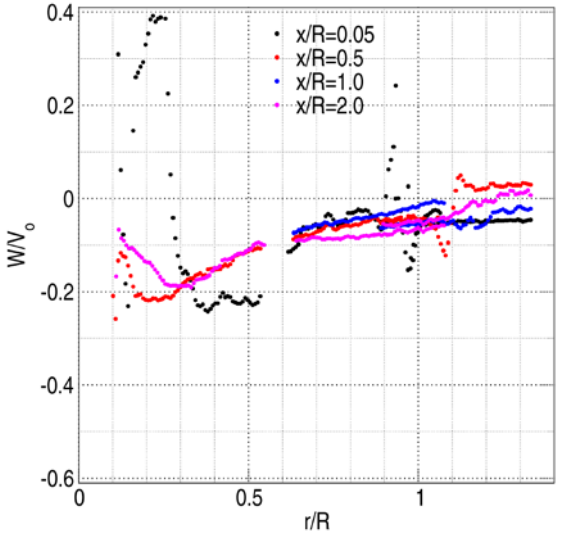


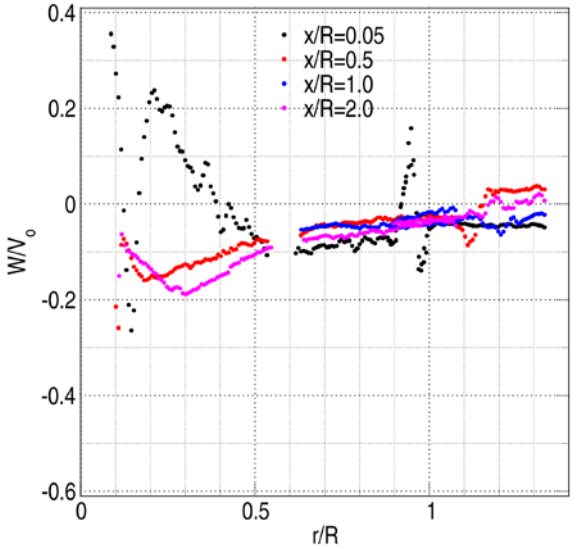


Tangentiel Vel, W-mean TSR 4-7

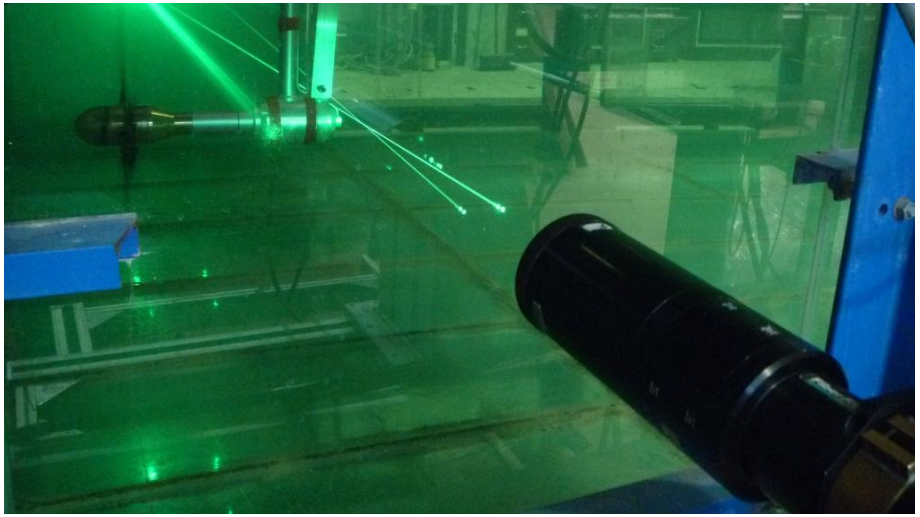


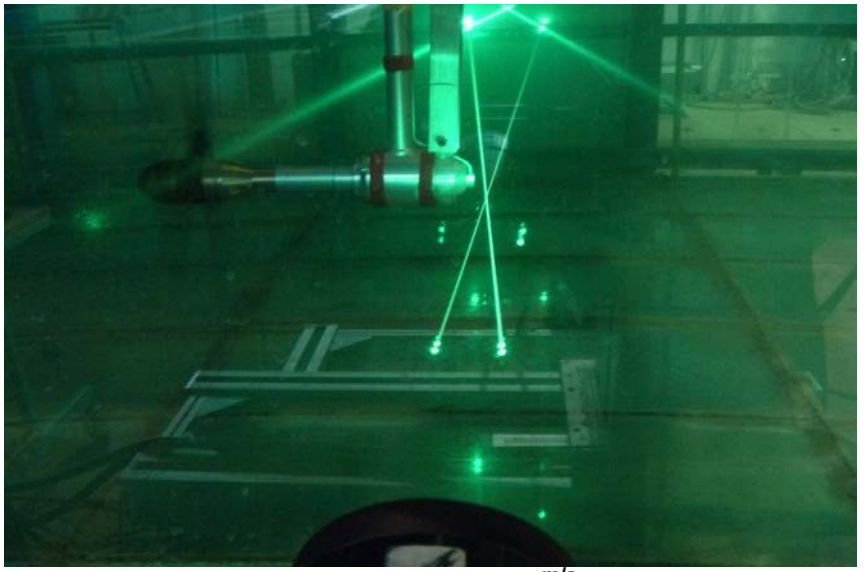


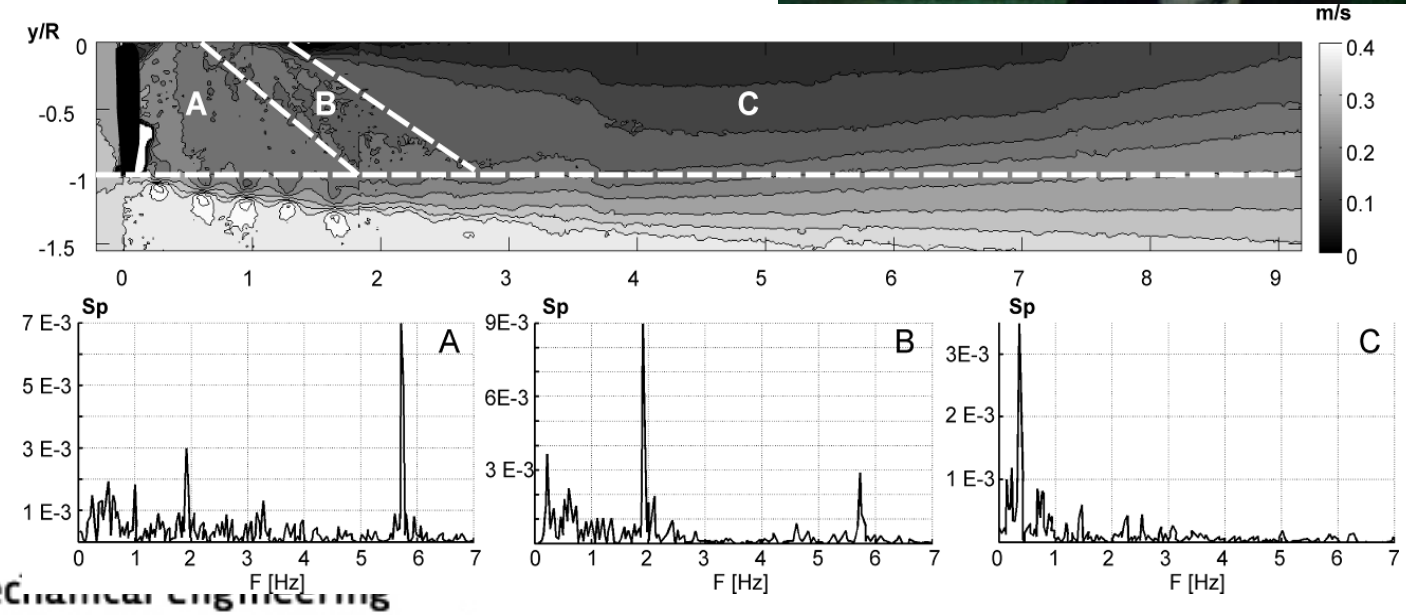




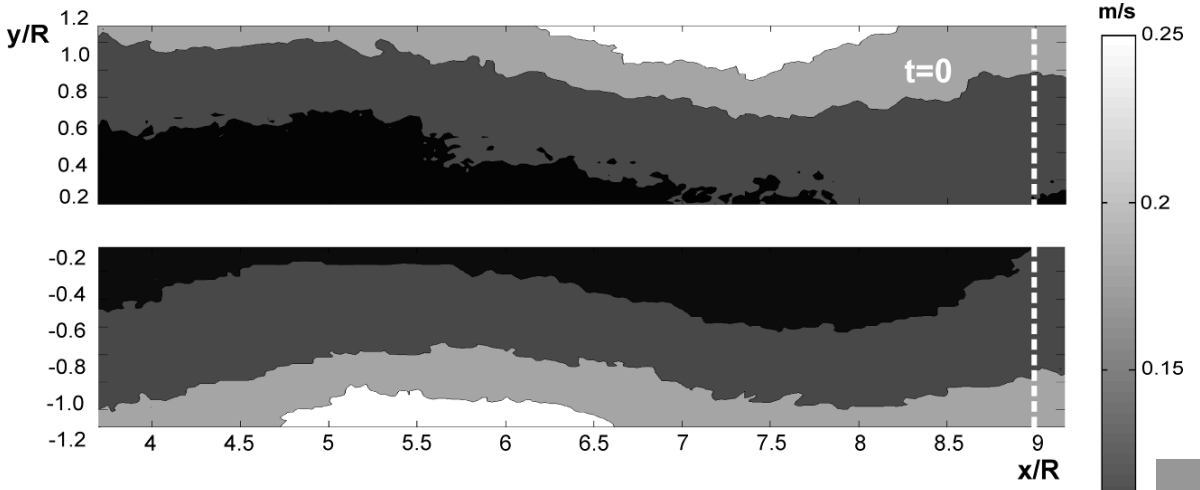
LDA prediction of wake frequencies

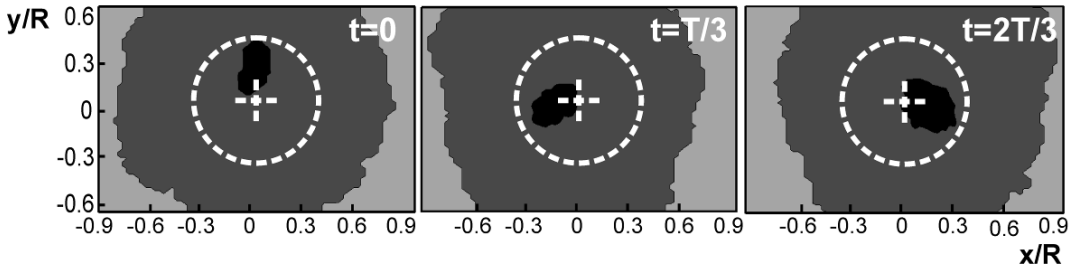


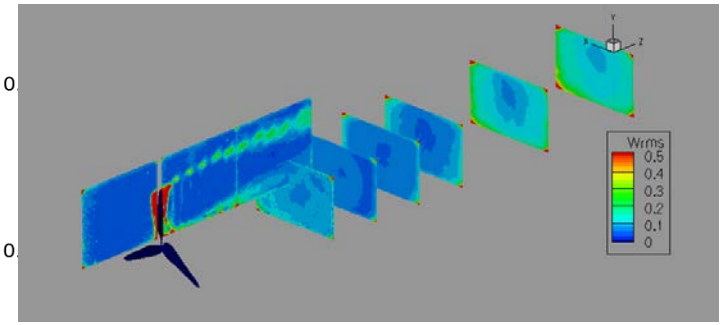


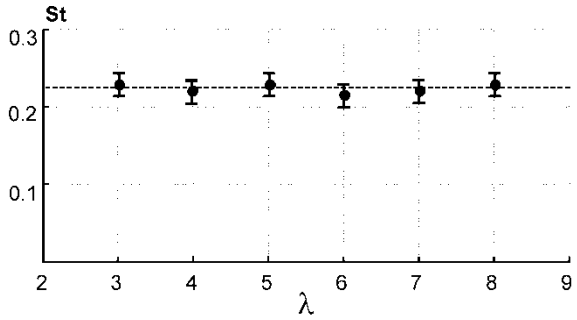


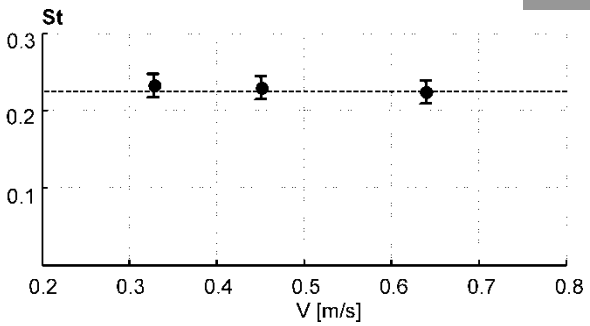
LDA prediction of wake frequencies











Summary

Experimental investigation of the rotor by Glauert Opt. of TSR = 5 was made at TSR 3-8 :

- **Power and trust coefficients**
- **Circulation along blade**
- **Visualization captures dynamics of helical structures**
- **PIV-mapping of the flow in the wake**
- **LDA measurements - frequencies**

Conclusions

- **The wake pitch keeps a constant in axial direction**
- **The wake expansion coincide with the prediction of the actuator disk theory**
- **The far wake with double of the axial factor may be indicated before the wake breakdown**
- **Characteristic frequencies in the wake: blade, rotor and Strouhal**
- **The wake breakdown with a reduction of the axial factor displays under small Re = 20000 too**